Sandia BOS Testing

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Hybrid Battery Management

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Background

Most batteries used in PV systems are designed for deep-cycle motive power or standby float service applications. In these applications they are deep-cycled and fully recharged every day or maintained at a 100% state-of-charge. Information from battery manufacturers is primarily oriented toward these markets since they constitute the majority of sales. In PV hybrid applications the available PV energy may be insufficient to completely recharge the battery and it may be undesirable to operate an engine-generator for the prolonged time periods required to finish charge a battery every cycle. Therefore, traditional battery deep-cycle or float service charging specifications can be inadequate for PV applications. In general, traditional charge settings will result in PV batteries that are under charged and thus require a longer duration finish charge when finally provided.

Unit Tested

Flooded lead acid and VRLA batteries

Objective

The purpose of this brief is to provide some basic battery-management guidelines. Because there are so many factors affecting battery performance and lifetime, battery-management advice can be difficult to quantify. Although the variety of battery considerations prohibit a single solution, reasonable guidelines can still be developed. The battery manufacturer is the final authority.

Test Procedure

The conclusions itemized below result from experience with several fielded systems. In these systems consistent undercharging resulted in loss of battery capacity. After the setpoints were raised and/or finish charge times were increased, the battery capacity was stablized or recovered.

Typical Charge Cycle

Without a capacity test the battery state-of-charge is only estimated, either by counting ampere-hours, or, more crudely, by measuring battery voltage. The battery charging process is very inefficient as the battery reaches full charge. Therefore, to return to the initial state of charge requires more ampere-hours in than were taken out during the discharge. Some percentage of overcharge is required to compensate for this, but the amount of overcharge is subject to battery history, type, and charging parameters. When battery voltage is used as the indicator for state of charge, available capacity is dependent on discharge rate and battery design or type. Because of these uncertainties, a charge deficit can build, resulting in battery damage or capacity fade. A complete finish charge or equalize charge is required to prevent or minimize this capacity loss.

Normal Charge Algorithm. A typical charge cycle for a flooded lead-acid cell is illustrated in the figure. At the beginning of the charge cycle, the system is providing energy to the load from the battery. When the system controller detects that the battery state-of-charge has dropped below a pre-selected minimum, it starts a generator and begins charging the battery.

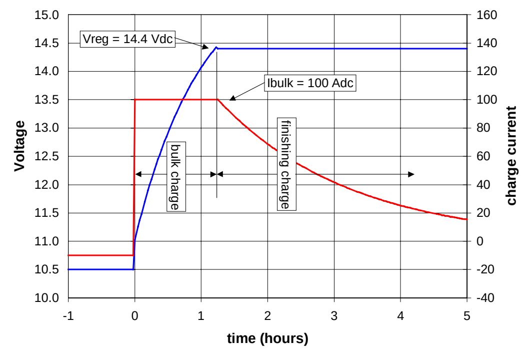
Bulk Charge. As the name implies, bulk charging is intended to replace the bulk of the charge that has been removed from the battery. Bulk charge is normally done with as much charge current as (1) is available from the generator and (2) can be accepted by the battery. As the battery charge builds, battery voltage rises.

Finishing Charge (current taper). When the battery voltage reaches its regulation charge voltage setting, the charge current is gradually reduced to maintain this voltage value. Two common control methods when charging with an engine are (1) terminate the charge when the regulation voltage has been maintained for a predetermined period of time or (2) terminate the charge when the current has tapered to a predetermined level. At this time, a "normal" charge cycle is completed and the system controls turn off the generator and return to inverter operation.

Normal Charging is a Tradeoff. The optimum time to stop the charge is a tradeoff between battery treatment and extended generator run time at low loading. From a battery standpoint, the optimum recharge would be to maintain the regulation voltage for an extended period of time. Many small inverter/chargers reduce their regulation voltage to a lower float voltage and maintain that value indefinitely as long as ac power is available. This approach can be effective in applications such as boats or recreational vehicles because grid power is available and the battery can be floated for long periods of time between discharges with no significant economic penalty. However, in an engine-generator system the penalties associated with long run times at low loading may include additional fuel consumption, inefficient engine operation, noise, and emissions.

Equalization. A periodic equalization charge can help compensate for the harmful effects resulting from incomplete recharges or capacity fade of individual cells. During equalization the vented battery is maintained at an elevated regulation voltage, i.e., higher than the regulation voltage for a normal bulk charge, for an extended period of time. As in the case of an extended finish-charge, maintaining this condition to fully recharge the battery exacts an economic penalty in the form of engine-generator run time at low loading.

Temperature Compensation. Because the battery's electrochemical processes are affected by temperature, the battery accepts charge more easily when warm than when cold; as a result the regulation voltage values must be adjusted for temperature. In cold weather, a higher regulation voltage is needed for complete recharge and in warm weather, a lower regulation voltage is needed to avoid excessive charge and loss of water.



Results

Guidelines. Our test results on PV hybrid systems indicate that the recommendations below are a good starting point for regulation voltage, charge algorithm, and system design. These values are not intended to replace manufacturer's recommendation, but to give general guidelines. They are based on data from a variety of laboratory and fielded battery systems. Note that voltages are given on a per-cell base and a 12-volt base.

Table 1 Vented

Variable	Minimum (Hybrid) Lead-Antimony	Maximum/Equalize Lead-Antimony
PV regulation voltage (Vr) @ 25°C Constant Voltage On-Off (Vrr -Vr)	2.40 to 2.50 vpc (14.4 to15.0) 2.28-2.45 vpc (13.7-14.7) min	2.55 vpc (15.3) 2.28-2.55 vpc (13.7-15.3)
Engine-gen Vr @ 25°C	2.40 to 2.55 vpc (14.4 to 15.3)	2.55 vpc (15.3)
Engine-gen Time @ Vr	0 to 3 hr.	5 to 12 hr. – (15 to 30-day max interval with daily cycles)
Engine-gen start voltage (Minimum)	1.95 vpc (11.7)	2.0 vpc (12.0)
Temperature coefficient V/°C/cell	-0.005	-0.005

Table 2 VRLA

Variable	Minimum (Hybrid) VRLA	Maximum/Equalize VRLA
PV regulation voltage (Vr) @ 25°C (Use Manufacturers Specs) Constant Voltage On-Off (Vrr -Vr)	2.35 or 2.40 vpc (14.1 or 14.4) 2.28-2.37 vpc (13.7-14.2) or 2.28-2.42 vpc (13.7-14.5)	2.35 or 2.40 vpc (14.1 or 14.4)
Engine-gen Vr @ 25°C (Use Manufacturers Specs)	2.35 vpc (14.1) or 2.40 vpc (14.4) Constant Voltage	2.35 vpc (14.1) or 2.40 vpc (14.4) Constant Voltage
Engine-gen Time @ Vr	0 to 6 hr. – (15-day max interval with daily cycles)	12 hr. – 15-day max Interval with daily cycles
Engine-gen start voltage (Minimum)	1.95 vpc (11.7)	2.0 vpc (12.0)
Temperature Coefficient V/°C/cell (Use Manufacturers Specs)	-0.005	-0.005

Significance

Adherence to battery-charging guidelines that have been developed specifically for PV hybrid systems can significantly enhance battery lifetime.

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